ECEN 150 Lab 11 – Impedance

Name:

Purposes: (46 points total)

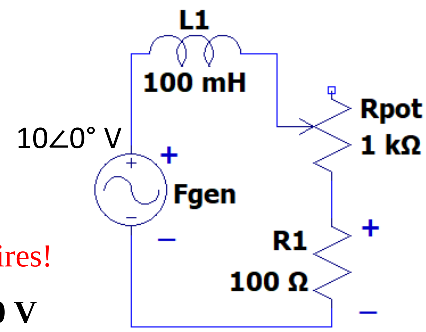
- Practice calculating impedance in RL and RC circuits.
- Experimentally demonstrate how impedance changes with frequency and resistance.
- Practice setting up and using an oscilloscope to measure sinewaves.

Procedure:

Part 1. Construct an RL circuit. Calculate and measure its response to a sinusoid.

Step 1: Construct the RL circuit.

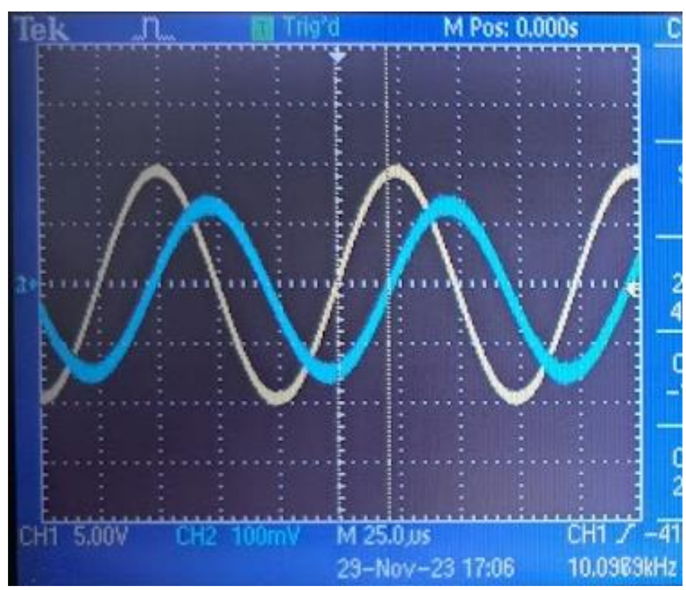
- Grab the following:
  - 100 mH inductor
  - Potentiometer (1 kΩ)
  - 100 Ω resistor



- Construct the circuit shown to the right on a breadboard. No wires!
  - Set the function generator to deliver a sinewave with **20 V peak-peak** (10 V magnitude) and **frequency at 10 kHz**.
  - Connect **CH1** of the oscilloscope to measure the function generator voltage (V_{Fgen}) (10X probe setting)
  - Connect **CH2** of the oscilloscope to measure V_{R1}. (10X probe setting)

Step 2: Measure the circuit response.

- Hit “autoset” on the oscilloscope for an initial configuration.
- Adjust the waveform displays until they are centered, zoomed in, and overlapping.
  - It should look like this: →
  - *Ensure both channels are set to AC coupling, not DC. These are settings in the CH1 and CH2 menus. Ask for help if you are unsure of how to do this.



- *Note: CH2 is an indirect measure of the current through the circuit since $V_{R1}(t) = i(t)*R1$.

Question 1: Is the current (CH2) leading or lagging the applied voltage (CH1)? _____lagging______ (1pt)

(*Hint: lagging means it occurs *later* in time; i.e., shifted right. Leading means earlier; shifted left)

Question 2: Does your answer from Question 1 indicate that this circuit has current inertia, or voltage inertia? Does this match the expectation for a circuit containing an inductor (and no capacitor)? Answer below in 1-2 complete sentences. (2 points)

(Answer here in 1-2 complete sentences) Current inertia because it takes time for the current to change, it's not instantaneous. It does match for a circuit containing an inductor because voltage can change instantaneously across and inductor but not the current.

Step 3: Observe the impact of varied resistance at 10 kHz.

- Vary the potentiometer from minimum to maximum resistance value. Observe CH2 for any changes in current.

Question 3: Do you observe any significant change in current as Rpot varies, either in terms of magnitude or phase? _____No_____ (1 pt)

- To explain your observation in Question 3, calculate the inductor reactance X_L and the circuit impedance ***Z*** (magnitude and phase) and **enter the answers in Table 1** below.

*Hints: X_L should be around 6.3 kΩ, as should |Z| be in both cases. ϕ_{RL} should be between 80-90° in both cases.

Table 1 **Frequency**	**Total resistance (Rpot + R1)**	**Inductor Reactance** $X_L = 2\pi f L$	**RL circuit impedance: |Z| ∠ ϕ_{RL}** — **Magnitude |Z|** $\lvert \mathbf{Z} \rvert = \sqrt{R^2 + {X_L}^2}$	**Phase ϕ_{RL}** $\phi_{RL} = \tan^{-1}\left(\frac{X_L}{R}\right)$
10 kHz	Rpot at min: 0 Ω + 100 Ω = 100 Ω	____6283_____ Ω (1 pt)	____6283_____ Ω (1 pt)	____89_____ ° (1 pt)
	Rpot at max: 1 kΩ + 100 Ω = 1.1 kΩ		____6378_____ Ω (1 pt)	____80_____ ° (1 pt)

- The circuit current is **I** = **V** / **Z.** Since we are measuring the current as the voltage across R1, CH2 is measuring V_{Ch2} = 100 Ω * |I| = 100 Ω * 10 V / |Z|.

Question 4: What is the expected (**calculated**) peak voltage at CH2? (V_{Ch2} = 100 Ω * 10 V / |Z|)
____0.159 V______ (1 pt)

Question 5: What is your **approximate measured** peak voltage at CH2? (it should be close to your value in Question 4. Use the volts per division to estimate the value on the oscilloscope.)

_____0.156 V_____ (1 pt)

Question 6: Use your calculated results from the table to explain your observation in Question 3. Why isn't the current varying much as we change Rpot? Remember: **I** = **V** / **Z**. (Be sure to reference both the magnitude and phase of the impedance in your answer.) (2 points)

(Answer here in 1-2 complete sentences)

The circuit has a really big magnitude of impedance so changing Rpot doesn't really do much in comparison since it's the square root of the sum of their squares.

Step 4: Observe the impact of varied frequency.

- Now vary the function generator frequency from 10 kHz to 20 kHz. Observe CH2 for any changes. Then vary frequency from 20 kHz to near-zero Hz.

Question 7: Is current (CH2) increasing or decreasing as frequency **increases**?
____decreasing______ (1pt)

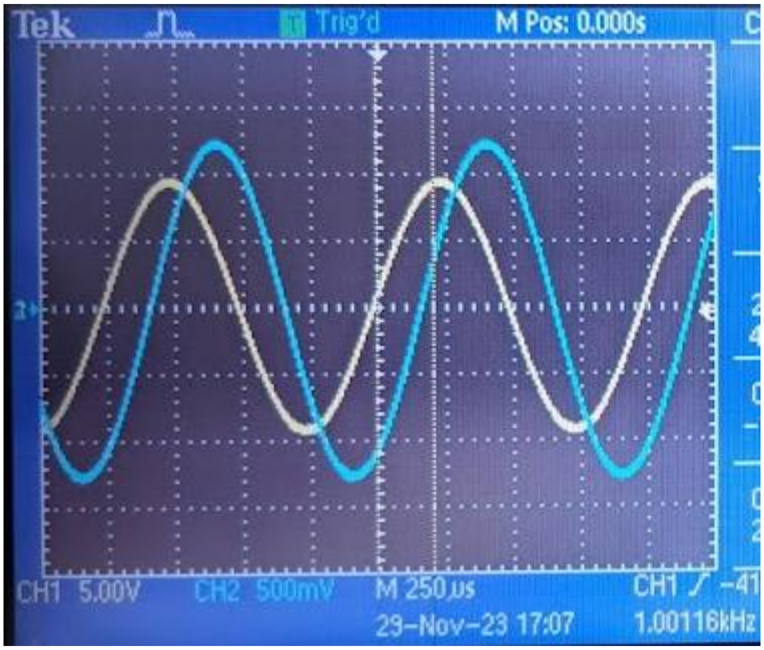
Question 8: Does your answer in Question 7 indicate an overall increase or decrease in total circuit impedance as frequency **increases**? Include the expected change in inductor impedance at high frequency to explain your answer. (2 points)

(Answer here in 1-2 complete sentences)

Impedance will increase as frequency increases because as frequency increases, so does the reactance and the increase of reactance increases the impedance. This matches question 7 because an increase in impedance should make the current decrease.

Step 5: Observe the impact of varied resistance at 1 kHz.

- Change the function generator frequency to 1 kHz. Hit "autoset" on the oscilloscope.
- Adjust the waveform scale and position until it looks like the below. *Shown below with Rpot set to a minimum.



- Vary the potentiometer from minimum to maximum resistance value. Observe CH2 for any changes in current.

Question 9: Do you observe any significant change in current as Rpot varies, either in terms of magnitude or phase? ____Yes in magnitude______ (1 pt)

- To explain your observation in Question 9, calculate the inductor reactance X_L and the circuit impedance ***Z*** (magnitude and phase) and **enter the answers in Table 2** below.

Table 2 **Frequency**	**Total resistance** **(Rpot + R1)**	**Inductor Reactance** $X_L = 2\pi f L$	**RL circuit impedance: |Z| ∠ ϕ_{RL}**	
			Magnitude |Z| $\lvert \mathbf{Z} \rvert = \sqrt{R^2 + {X_L}^2}$	**Phase ϕ_{RL}** $\phi_{RL} = \tan^{-1}\left(\frac{X_L}{R}\right)$
1 kHz	Rpot at min: 0 Ω + 100 Ω = 100 Ω	____628_____ Ω (1 pt)	_____636____ Ω (1 pt)	_____81____ ° (1 pt)
	Rpot at max: 1 kΩ + 100 Ω = 1.1 kΩ		_____1267____ Ω (1 pt)	_____30____ ° (1 pt)

Question 10: Use your calculated results from the table to explain your observation in Question 9. Is **Z** now changing with R? What does this do to the current? Remember: **I** = **V** / **Z**. (Be sure to reference both the magnitude and phase of the impedance in your answer.) (2 points)

(Answer here in 1-2 complete sentences)

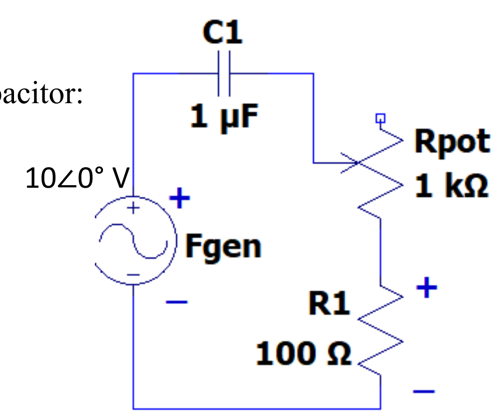
Yes Z is changing with R. As R increases, the impedance increased in magnitude and the phase changed and the current also increases because with a smaller impedance, resistance makes a bigger difference.

Part 2. Construct an RC circuit. Calculate and measure its response to a sinusoid.

Step 1: Construct the RC circuit.

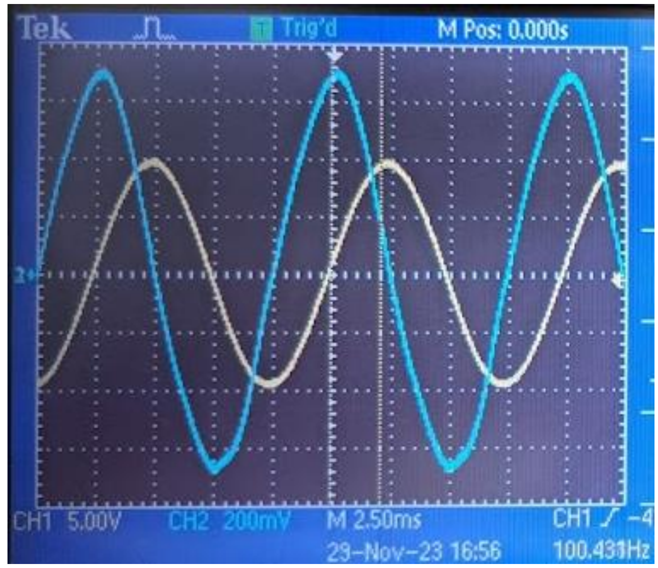
- Replace the inductor in your circuit with a 1 μF ceramic capacitor:

- Set the function generator frequency to **100 Hz**.



Step 2: Measure the circuit response.

- Hit “autoset” on the oscilloscope for an initial configuration.
- Adjust the waveform scale and position until it looks like the below. *Shown with Rpot set to a minimum.



Question 11: Is the voltage (CH1) leading or lagging the current (CH2)? _____lagging______ (1pt)

Question 12: Does your answer from Question 11 indicate that this circuit has current inertia, or voltage inertia? Does this match the expectation for a circuit containing a capacitor (and no inductor)? Answer below in 1-2 complete sentences. (2 points)

(Answer here in 1-2 complete sentences)

It would have voltage inertia because with the capacitor it resists changes to voltage so it takes some time to get it going and charge up. So that means it also matches the expectation for a RC circuit.

Step 3: Observe the impact of varied resistance at 100 Hz.

- Vary the potentiometer from minimum to maximum resistance value. Observe CH2 for any changes in current.

Question 13: Does the current (CH2) magnitude vary with Rpot? _____Yes______ (1pt)

Question 14: Does the current (CH2) phase vary with Rpot? _____Yes______ (1pt)

- To explain your observations in Questions 13-14, calculate the capacitor reactance X_C and the circuit impedance ***Z*** (magnitude and phase) and **enter the answers in Table 3** below.

*Hints: X_C should be around 1.6 kΩ. ϕ_{RC} should be around -54° at high Rpot, and around -85° at low Rpot.

<table>
<tr><th rowspan="2">Table 3
Frequency</th><th rowspan="2">Total resistance
(Rpot + R1)</th><th rowspan="2">Capacitor Reactance
$X_C = 1 / (2\pi f C)$</th><th colspan="2">RC circuit impedance: |Z| ∠ ϕ_{RC}</th></tr>
<tr><th>Magnitude |Z|
$|Z| = \sqrt{R^2 + X_C{}^2}$</th><th>Phase ϕ_{RC}
$\phi_{RL} = \tan^{-1}\left(\frac{-X_C}{R}\right)$</th></tr>
<tr><td rowspan="2">100 Hz</td><td>Rpot at min:
0 Ω + 100 Ω = 100 Ω</td><td rowspan="2">____1591_____
Ω
(1 pt)</td><td>____1594_____ Ω
(1 pt)</td><td>____-86_____ °
(1 pt)</td></tr>
<tr><td>Rpot at max:
1 kΩ + 100 Ω = 1.1 kΩ</td><td>____1934_____ Ω
(1 pt)</td><td>____-55_____ °
(1 pt)</td></tr>
</table>

Question 15: Use your calculated results from the table to explain your observation in Questions 13-14. Why does varying Rpot impact the magnitude and phase of the current? (Be sure to reference both the magnitude and phase of the impedance in your answer.) (2 points)

(Answer here in 1-2 complete sentences)

The magnitude and phase of the impedance is small compared to the magnitude of the resistance. And with a greater resistance, the more voltage is dropped across it so the numerator for I would be larger than the denominator meaning I will increase as R increases.

Step 4: Observe the impact of varied frequency.

- Now vary the function generator frequency from 100 Hz to 200 Hz. Observe CH2 for any changes. Then vary frequency from 200 Hz to near-zero Hz.

Question 16: Is current (CH2) increasing or decreasing as frequency **increases**?
_____increases_____ (1pt)

Question 17: Does your answer in Question 16 indicate an overall increase or decrease in total circuit impedance as frequency **increases**? Include the expected change in capacitor impedance at high frequency to explain your answer. (2 points)

(Answer here in 1-2 complete sentences)

As the frequency increases, the impedance decreases. Frquency is in the denominator so the bigger the denominator the smaller the impedance.

*****Demo your oscilloscope measurement to the TA; then take Lab 11: Quiz 1*****

Part 3. Conclusions statement.

Write a brief conclusions statement that discusses all the original purposes of the lab. Please use complete sentences and correct grammar to express your thoughts on how you fulfilled the purposes of the lab:

Purposes (repeated):

- Practice calculating impedance in RL and RC circuits.
- Experimentally demonstrate how impedance changes with frequency and resistance.
- Practice setting up and using an oscilloscope to measure sinewaves.

Conclusions (7 points):
In this lab we practiced calculating impedance in both RL and RC circuits and then measured changes in voltage (and therefore current) using the oscilloscope to see what would happen to the impedance of the circuit with changes in frequency and changes in resistance. We practiced using the oscilloscope with sinewaves this time since we were dealing with and AC circuit this time.

Congratulations, you have completed Lab!
You may now submit this document.